Hybrid Time-Frequency Domain Adaptive Filtering Algorithm for control of the vibration control systems

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Abstract
Hybrid Time/Frequency-Domain Adaptive Filtering (HTFDAF) algorithm is proposed for identification and control of the vibration control systems in which the electrodynamic shaker is used to generate vibratory force/acceleration. In such case, the model and controller of the electrodynamic shaker and its load is adaptively modelled using Finite Impulse Response (FIR) block frequency-domain filtering algorithm instead of the time-domain method. The standard frequency domain adaptive filtering (FDAF) has disadvantage of inherited long delay due to input block processing. Splitting the adaptive filter weights into non-overlapping partitions reduces the delay in the system. Although this method of splitting the filter weights into partitions had resulted in reduction of the delay in the system but it does not eliminates it completely. In this paper we proposed the (HTFDAF) method where the filter weights are split into partitions and the weights of the first partition is updated using the time-domain algorithm during the initial stage of the input block processing. Then starting from the second block index iteration, the first partition’s weights will be updated together with other remaining partitions weights in the frequency-domain. This method of the updating the first partition’s weights using time only in the initial stage of input block processing will result in reduction of computational complexity of the adaptive process.

Keywords: Adaptive Filtering, Frequency-domain adaptive filtering
I. Introduction
Electrodynamic shakers are usually used in the vibration control system to generate the required vibratory force to excite the mode of the device under test (specimen). In order to prevent the damage of the vibration apparatus (shaker, device under test), it is essential to control the accelerating force generated by the exciter such that it should not exceed the limit capacity of the devices and to ensure that the exciter is operating in the specified range of its operation. Usually, in the vibration control using the shaker, the load dynamic is not well defined before hand. Therefore, to decide on the adequate type of the controller for vibration systems, the following point must be put in consideration:

• The controller should be able to update its parameters to cope with load uncertainty.
• The controller must have fast response especially when the pulse used is shock pulse.
• The controller must be robust, such that it can adapt to large range of load variations.

Vibration control using Frequency Domain Adaptive Filtering algorithm has been reported in [6]. Our proposed algorithm of adaptive controller is mainly differ than the one reported in [6], in the following aspects: a) The time domain adaptive filter of the model and its inverse are sequentially split into non-overlapping partitions, b) The first partition weights are updated in the time domain during the first block input data collection, then they are adapted in the frequency domain in the remaining adaptation period with the other partitions weights.

This paper is divided as follows: section II discusses the shaker model identification using HTFDAF algorithms. In section III the control algorithm was derived using HTFDAF combined with filtered-x algorithms. Computational load of the different time/frequency domain algorithms was summarised in section IV. In section V simulation results was discussed. Section VI present the conclusion.

II Problem description and model identification
Given the desired reference acceleration it is required to design an adaptive controller for the electrodynamic shaker loaded the test specimen such that the shaker output converge to the reference input in a short time and without excessive overshoot.

With the above objectives in mind, we proposed Hybrid Time-Frequency Domain Adaptive Filtering algorithms (HTFDAF). In which the model and inverse model (Controller) of the electrodynamics shaker are modelled by FIR. We found that the transfer function of the model and inverse model of the shaker required thousand of FIR weights to represent the system dynamic (shaker and load attached on its table) effectively. This large amount of filter taps results in complex computation and its implementation in real-time need large resources in term of memory.

Figures (1) and (2) show the measured and simulated frequency response of the shaker loaded with inertia mass of .557 kg. Figure (3) compared the shaker and computed model output when the input shock pulse of the rectangular shape was used. While figure (4) illustrate the output of the controlled shaker system when the inverse adaptive model was cascaded with the shaker. In figure (5), the inverse controller output and shaker controlled output are plotted. This figure shows that the shaker’s output converge to the desired reference acceleration.

Conclusion
As a result of the above-mentioned problems (Computational complexity, memory requirements), it was impossible to use the time-domain filtering methods to find the model and inverse model of Electroodynamics shaker and its load. Computational complexity and convergence speed of FIR model’s weight to their optimal values was addressed using frequency domain-Adaptive filtering algorithm rather than time-domain adaptive filtering to avoid the convergence rate dependence on the input correlation eigenvalue spread.
But the Frequency Domain Adaptive Filtering algorithm has a drawback of the delay inherent between the block input and the output response of the system especially during initial stages while the input block data collection is in process. This problem of the long delay in frequency domain adaptive filtering was addressed by splitting the time domain filter weights sequentially into non-overlapping partitions [1-4]. This partitioning of the filter weights had results in small size of the input block but still it does not completely eliminate the delay in the system. The delayless Frequency Domain Adaptive filtering algorithm was proposed in [5], where the delay in the system is eliminated by adapting the first partition weights using the time domain algorithm and adapting the remaining of partitions using frequency domain adaptive filtering algorithm through out the adaptation time. Although this method has eliminates the delay, but it contributed to increases of the computational complexity of the algorithm due to the time domain adaptive filtering of the first partition. To reduce the computational complexity of the Partitioned Frequency Domain Adaptive Filtering, we proposed the Hybrid Time-Frequency Domain Adaptive Filtering algorithm (HTFDAF), where the time domain filter weights are sequentially divided into non-overlapping partitions. The first partitions weights are adapted using the time domain only during the initial stage. That to say, time domain adaptation of the first partition take place only during first block of the input, then after that these weights are adapted using the frequency domain algorithm as well as the other partition’s weights. This way of partially updating some weights in the time domain and then in frequency domain of the first partitioned weight reduces the computational complexity of the whole adaptation process.
Figure 5. i. Controller output ii. Shaker controlled output

Figure 6 shaker controlled output (practical)

References


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